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(54) Method and apparatus for using shuttered windows in a micro-electro-mechanical system

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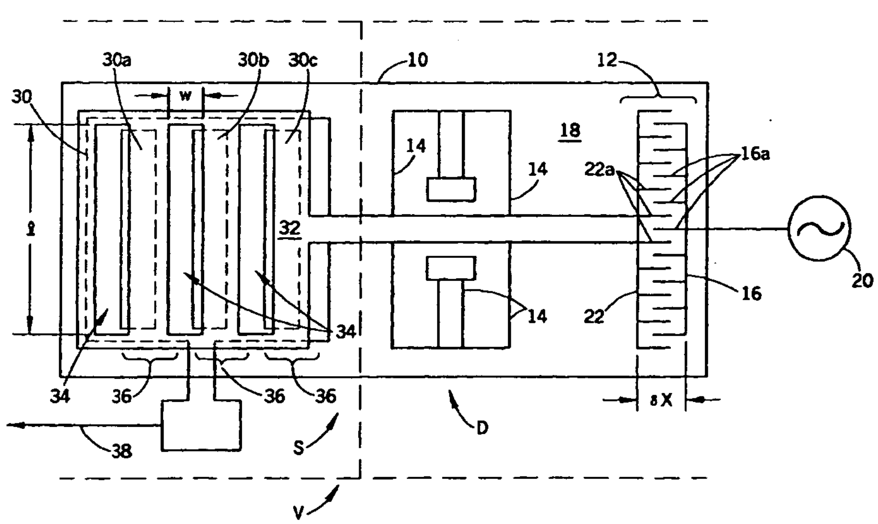

FIG.1

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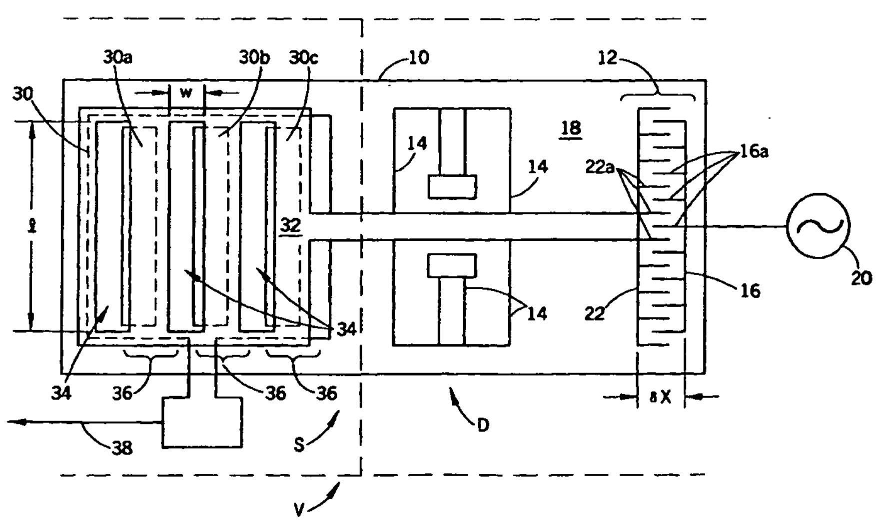

FIG.1

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displacement of the comb drive.

[0009] In accordance with still another aspect of the present invention, a method of increasing an output signal produced by a non-contacting voltmeter is provided. A moveable shutter is placed adjacent to a plurality of sensed probes. The moveable shutter has a plurality of windows spaced therein to expose the sense probes in a first position and to cover the sense probes in a second position. The shutter is then moved between the first and second positions thereby increasing the output signal produced.

Figure 1 is a depiction of an electrostatic voltmeter according to the present invention;
Figure 2 is a schematic view of an electrostatic copier/printer incorporating the electrostatic voltmeter; and
Figure 3 is a detail of the voltmeter from Figure 2.

[0010] The FIGURES show a voltmeter **V** that generally includes a driver component **D** and a sensor component **S**. More specifically, and with particular reference to FIGURE 1, a microstructure **10** has a driver component **D** configured as a comb drive **12** with a cantilevered spring arrangement **14**. The comb drive **12** is a common mechanism for electrostatically driving microstructures and includes a fixed side **16** attached to a substrate **18**. The comb drive is electrically connected to an electrostatic drive signal source **20**. A movable side **22** of the comb drive is held to, but above, the substrate **18** by the cantilevered spring arrangement **14**. A plurality of comb "fingers" **16a, 22a** are interdigitated to provide electrical communication between the fixed side **16** and the movable side **22**. The length of these fingers define a maximum potential displacement, δx.

[0011] The driver component **D** shown is FIGURE 1 is understood to be merely a representative structure that would fulfill the objects of the present invention. However, other driver components are also encompassed by this disclosure such as magnetostatically and thermally driven microstructures among others.

[0012] Operatively associated or connected to the driver component **D** is the sensor component **S**. In this preferred embodiment, the driver component **D** is disposed opposite or linearly adjacent the sensor component, although it will be appreciated that other geometric arrangements may be used without departing from the scope and intent of the subject invention. A sense probe assembly **30** is fixed to the substrate **18** and is capable of capacitive coupling with a surface to be measured. The sense probe assembly is a set of spaced individual sense probes (represented here by numerals **30a, 30b, 30c**, etc.) The individual sense probes are connected together so that individual signals are combined. The sensor component **S** further comprises a movable shutter **32** that selectively overlays the sense probe assembly **30**. Here, the shutter is mechanically connected to driver component **D** so that linear displacement of the driver component results in a corresponding displacement of the shutter. The shutter **32** has a plurality or set of openings or windows **34** configured such that the sense probe assembly **30** is selectively exposed through the windows **34** when the shutter **32** is in a first position. The individual shutter openings are spaced from one another by a dimension matching the individual sense probe spacing. When the shutter **32** is in a second position, the sense probe assembly **30**, or individual sense probes, is/are covered by the shutter regions **36** interposed between the windows. In other words, when the shutter **32** is in the first position, capacitive coupling by the sense probe assembly **30** is permitted. On the other hand, when the shutter is in the second position capacitive coupling by the sense probe assembly is masked or inhibited. The current generated by the sense probe assembly **30** is output on line **38**.

[0013] The windows **34** define a length l and a width w. In a presently preferred embodiment, the width w is on the order of 10μm and is slightly less than the maximum potential displacement δx. Similarly, each shutter region **36** separating the windows is substantially equal to the maximum potential displacement δx.

[0014] One skilled in the art can now appreciate that this change in geometry has the desirable effect of using a small drive displacement, $\delta\chi$, to advantageously provide a greater change in the modulated area. Said another way, the modulated area is $(n)(\delta\chi)(\ell)$, or n times as large as the shutter without windows (where n is the number of windows **34** in the shutter **32**). For ease of reference, a modification of Equation 4 is shown here so that the benefit of increased area may be appreciated mathematically:

$$C(t)=C_o+\varepsilon_o\delta A/d\,\sin(\omega t)=C_o+\varepsilon_o n\ell\delta x/d\,\sin(\omega t), \qquad \text{EQ. 4'}$$

This increased area desirably increases the output signal.

[0015] The windows in the shutter **32** also contribute to increase the output signal. The windows make the shutter lighter, i.e., decreased weight, thus increasing the resonant frequency of the sense probe system. It follows that increased frequency (ω) yields increased shutter velocity ($\partial x/\partial t$) as shown by the following equations:

$$x=x_o\sin(\omega t), \qquad \text{EQ. 5}$$

thus,

$$\partial x/\partial t=\omega x_o \cos(\omega t), \quad \text{EQ. 6}$$

and

$$i_s(t)=V_{dc}dC(t)/dt=V_{dc}[\partial C(x,t)/\partial x][\partial x/\partial t], \quad \text{EQ. 2}$$

Therefore, increased velocity in turn yields an increased output signal.

[0016] Referring now to FIGURE 2, a xerographic type copier/printer **40** includes a photoreceptor **42** configured as a rotating drum. The present invention recognizes that other photoreceptor configurations, such as belts or webs are possible. A charge station **44** is provided where photoreceptor **42** is charged in preparation for imaging. During any of various operations (copying, printing, etc.), the photoreceptor **42** travels a path adjacent the voltmeter V after which an electrostatic image is placed on the photoreceptor **42**. Next, the photoreceptor **42** proceeds to a developer station **46** where the latent image created on the photoreceptor **42** is developed followed by a transfer station **48** where the previously developed image is transferred to a copy sheet **50**. Residual developer materials are removed from the photoreceptor **42** at cleaning station **52** prior to charging again at the charge station **44**. Details of the xerographic device and method of operation are generally known to those of ordinary skill in the art and the particular details form no part of the present invention.

[0017] FIGURE 3 shows a cross-section of the voltmeter V in the copier/printer **40** as described above. Cross-referencing FIGURE 1, the voltmeter V contains a comb drive **12** with a fixed side **16** attached to a substrate **18** and a movable side **22** movably attached to the substrate via a cantilevered spring arrangement **14**. The sense probe assembly **30** is shown attached to the substrate **18** with the movable shutter **32** between the substrate and the photoreceptor **42**.

[0018] Figures 2 and 3 are merely one representative example of the use of the present invention in a practical environment. The general principles, though, may be applied to related environments or applications. For example, flat panel display applications can incorporate the principle of the modulating light between first and second surfaces. Likewise, the preferred embodiment employed a single MEMS modulator in the electrostatic voltmeter application. However, one skilled in the art will readily appreciate the application of these principles to an array of modulators. For example, in an effort to sense and control page width, an array of modulators can be used to sense photoreceptor voltage at discrete locations. Moreover, although the displacement described with reference to the preferred embodiment of FIGURES 1-3 is linear, embodiments using angular displacements are also contemplated and deemed to fall within the scope hereof.

Claims

1. An electrostatic voltmeter comprising:

    a sense probe assembly for measuring a voltage by capacitive coupling;
    a shutter defining a plurality of windows movable between a first position where the sense probe assembly is exposed and a second position where the sense probe assembly is covered, the shutter being adjacent to the sense probe assembly; and
    a shutter driver operatively associated with the shutter for selectively moving the shutter between the first position and the second position.

2. The electrostatic voltmeter of claim 1 where each of the plurality of windows defines a length (l) perpendicular to the comb fingers and a width (w) parallel to the comb fingers, the width being equal to the maximum displacement.

3. A method to increase an output signal produced by a non-contacting voltmeter comprising:

    providing a plurality of sense probes;
    placing a movable shutter adjacent to the sense probes, the shutter defining a plurality of windows spaced to expose the sense probes in a first position, and cover the sense probes in a second position; and
    moving the shutter between the first position and the second position.

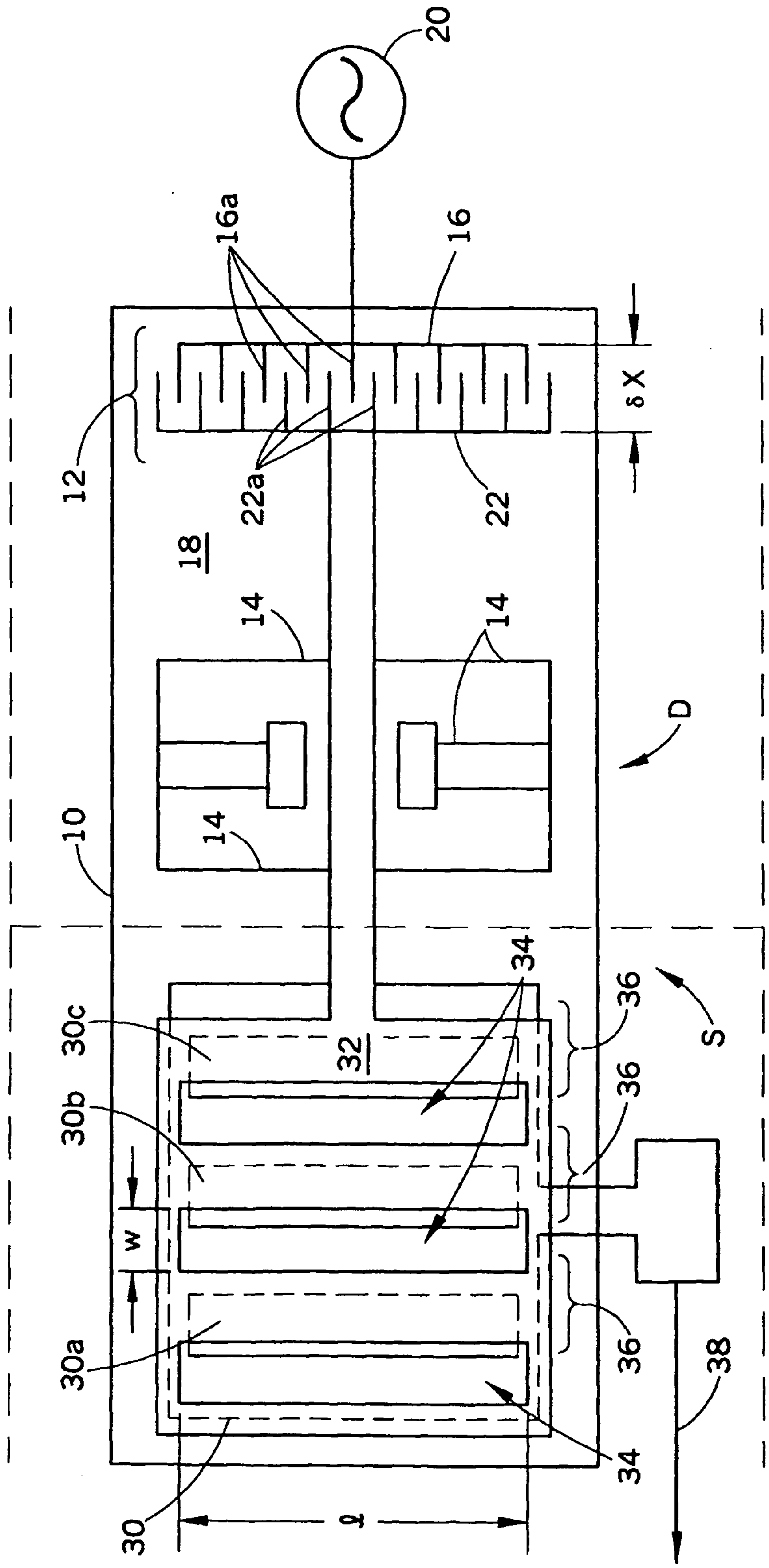
20
16a
16
12
22a
22
δX
18
14
14
14
14
D
10
34
36
S
V
30c
32
30b
36
w
30a
36
38
34
30
ℓ

FIG.1

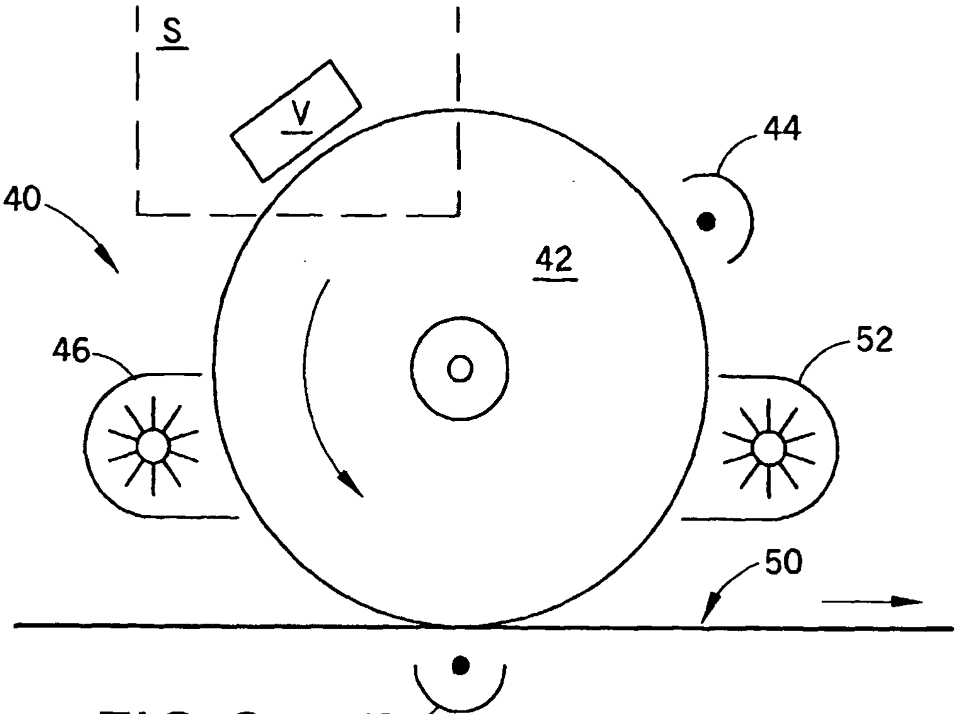

FIG.2

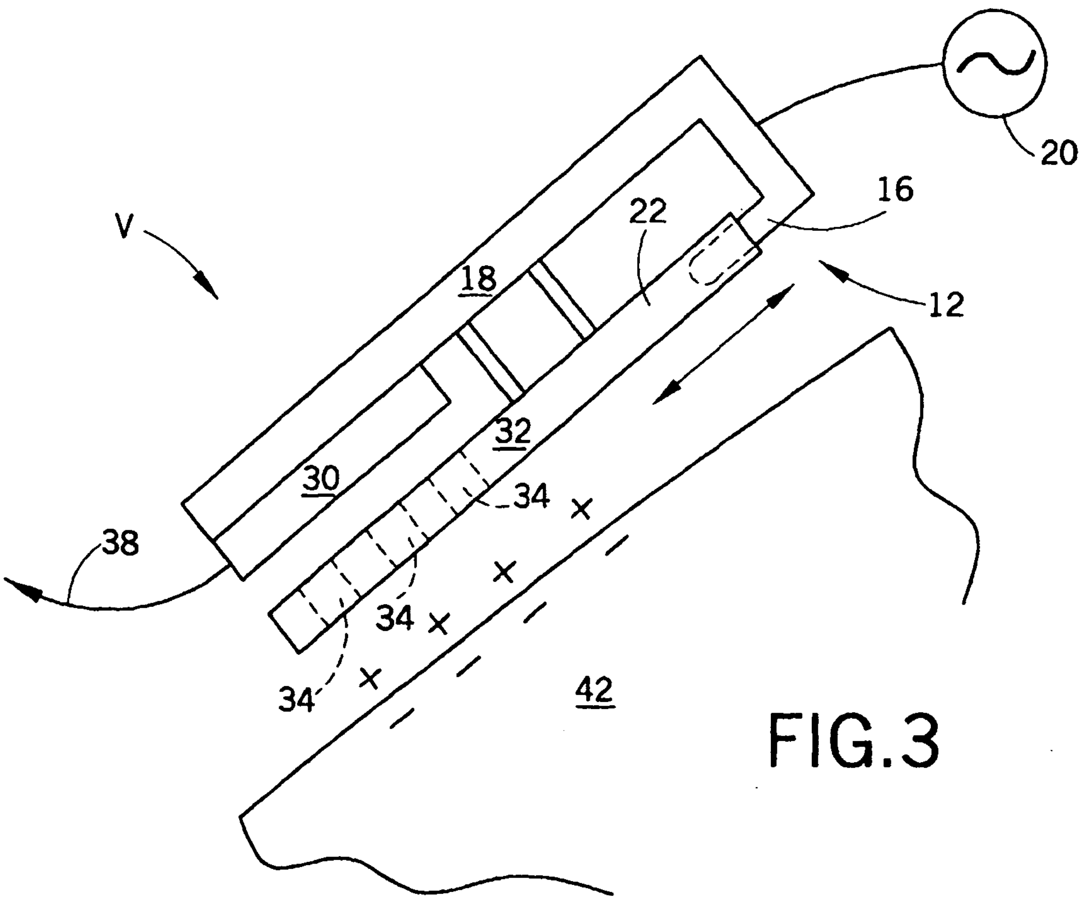

FIG.3